chapter three

ELEMENTS OF STUDY DESIGN

In recent years, public awareness about the importance and plight of **salt marshes** has grown. Local citizens have become increasingly active in environmental **monitoring** of salt marshes to assist with preservation or restoration efforts. It can be highly rewarding to take part in salt marsh monitoring — participants can learn about the natural communities of estuarine **wetlands** and share in public efforts to preserve and protect natural resources. However, it is imperative that volunteers collect data in an organized way so that the information they generate is useful to scientists and resource managers. This goal is easier than you think! The key to a successful monitoring program is a sound study design, which incorporates project goals, specific objectives and methods to be used, and procedures to ensure data quality. A study design requires that investigators think through and describe how to conduct monitoring to achieve project goals, and it should be in the form of a document that is read and understood by everybody involved in the monitoring program (Dates et al., 1997).

Successful volunteer monitoring programs usually have at least one thing in common: someone to coordinate the various activities, forays, meetings, training classes, logistics, equipment, data sheets, and report preparation. The project leader is the hub for the collective effort of the group, and pulls together all the various elements of the project to achieve results and maintain continuity. The project leader usually develops the study design and helps to ensure data quality and consistency, no matter where, when, or by whom the data were collected. Established monitoring programs may be fortunate enough to have funds to compensate the project leader, though in many cases the project leader is participating as a volunteer. There are many sources of funding and support — groups should consult with other volunteer and nonprofit environmental groups, state agencies, or federal agencies to explore funding opportunities (see Appendix A).

WHY MONITOR SALT MARSHES?

Why do you want to begin monitoring a wetland? How do you intend to monitor that wetland? What are you going to do with the data you collect? These questions may sound simple enough, but they need to be answered completely before you put binoculars around your neck, slide on chest waders, or sink your net into a tidal creek. To help define a monitoring program, volunteers should follow a three-tiered framework that involves defining goals, objectives, and applications.

Goal

What is the motivation for initiating a monitoring program? In the broadest sense, what would you like to accomplish? Many government agencies, private organizations, and volunteer monitoring groups all share the same goals yet use different means to accomplish those goals. Establishing goals at the outset of a project will help guide you through the process of defining objectives and applications, and will also help you identify potential partners and funding sources. Contact other nonprofit organizations, state agencies, and regional planning groups to see if you may be able to fill an existing gap for monitoring priority salt marsh sites.

Objective

You know what you would like to accomplish, but how are you going to do it? What steps must be taken? Objectives are the specific steps that need to be taken to accomplish a goal. Often several tasks are required to complete a specific objective. In planning for specific steps, it is helpful to estimate how long it will take to complete a task, who will do it, and when it will be completed. This planning helps to keep a project on track.

Application

What specific things do you hope to achieve with the results of your project? How can your data be used, and why are the data important? Applications are specific aims that can be achieved with your objectives. Applications are usually more specific than goals. Data can often be used in several different ways, and often there may be important applications of your data that were not part of the original intent of the project. For example, a project designed to assess the effect of a tide restriction on a salt marsh might also yield valuable data on loss of biological **diversity** or other threats to the marsh. Volunteers with a good understanding of salt marshes and conservation issues will have an easier time listing a variety of potential applications for a project.

WHAT TO MEASURE, HOW, AND WHEN

This manual provides guidelines and methods for four biological parameters and two physical/chemical parameters. There are many factors to consider when choosing which of these parameters to measure. Project leaders should weigh the pros and cons of each (Table 1), their relative cost and resources available, and the level of effort and expertise required (Table 2).

The project leader, with advice from agency staff and other professionals, will be largely responsible for selecting parameters, arranging training sessions, and scheduling fieldwork. Expertise of volunteers might be an important consideration when choosing parameters to measure — for example, if a volunteer has a strong background in botany, a group may consider monitoring vegetation. Volunteer monitors can gain a greater understanding of salt marshes by measuring several parameters, though they may achieve project goals by measuring only one parameter. It is better to sample fewer parameters carefully and thoroughly than to sample several parameters at the expense of data quality.

EXAMPLES OF GOALS, OBJECTIVES, AND APPLICATIONS

GOAL

- To describe the current condition of tide restricted salt marshes in Towns X and Y.

OBJECTIVE

- Contact state and regional groups.
- Collect background information, obtain ideas for possible sites.
- Hold kickoff meeting, invite interested locals.
- Select salt marsh sites, both **reference marshes** and study marshes.
- Determine **parameters** to sample, equipment needed, timing of sampling.
- Conduct **habitat assessment** of marsh **habitat** and surrounding landscape.
- Collect field data on selected parameters.
- Enter field data into spreadsheets.
- Analyze data.
- Hold community meeting to present results.
- Send results to state agency contact.

APPLICATION

- Select and prioritize marshes for conservation or restoration.
- Provide pre-restoration data on tide-restricted salt marshes in a certain area.
- Evaluate the effectiveness of a restoration project.
- Track the condition of a salt marsh over time.
- Document the plants and animals in a salt marsh.
- Assess the effects of **human disturbance** (i.e. pollution, development) on a salt marsh.

A small amount of good data is far better than a large amount of poor data! Volunteer data are more valuable to resource managers and scientists when groups have followed a study design and the guidelines and methods provided in the manual.

This manual emphasizes the use of metrics to represent wetland condition. Metrics, and the multimetric approach to assessing ecosystem health, are explained in the textbox on page 3-4.

TABLE 1. ADVANTAGES AND DISADVANTAGES OF MONITORING EACH PARAMETER COVERED IN THIS MANUAL

ADVANTAGES	DISADVANTAGES
TIDAL HYDROLOGY	
• Easy to take readings • Tidal restriction is easily observed and documented • Low level of effort	• Time-consuming as readings must be taken over tidal cycle
SALINITY	
• Relatively easy to take readings • Samples from pore water and surface water • Important chemical parameter	• Samples should be taken at multiple sites and times • Equipment must be calibrated • Affected by rainfall and seasonality
PLANTS	
• One or two surveys per season • Plants are relatively easy to identify • Plants integrate wide array of stressors such as salinity, hydrology, and substrate conditions	• Mobility on marsh surface may be difficult • Late/early season ID can be difficult • Difficult to isolate specific stressor
INVERTEBRATES	
• Wide range of organisms covering all trophic levels • Large number of organisms per sampling effort • Organisms complete their life cycle within the marsh, and reflect ambient and past habitat conditions • Well documented biology and ecology	• Sampling can be challenging in mud substrates • Sorting organisms from debris is time consuming • Identification of some taxa (especially polychaete worms) is difficult • Equipment costs are fairly expensive
FISH	
• Fish represent a higher trophic level than plants or invertebrates • Composition of marsh residents may reflect environmental conditions • Fun to collect, and thus foster an appreciation for these animals and their habitat • Salt marsh fishes are generally easy to identify	• Many samples (over several years) are often needed to accurately evaluate a fish population or community • Mobility of fish presents unique collection challenges • Sampling method often dictates which species are collected • Manpower (3 people minimum) • Equipment cost (i.e., bag seines)
BIRDS	
• Birds are popular with both the public and scientists and a large pool of proficient data collectors exists • The life history, ecology, and geographic distribution of birds is very well known • Easy and inexpensive to survey due to their visibility • Birds can indicate the integrity of landscapes since they can fly and easily move from one site to another • Birds are sensitive to habitat conditions and disturbance by noise, human visitation, and predatory animals (cats, dogs, raccoons, etc.)	• Birds present at a site will vary daily, seasonally, and randomly, and several visits are required to get accurate & representative data on wetland use by birds • Some sites are important for migration, feeding, or breeding, so surveys should be scheduled to capture all uses • Most bird identification is done by sound so surveyors need to be proficient with bird calls

TABLE 2. COSTS AND TIME COMMITMENT FOR EACH PARAMETER

PARAMETER	EQUIPMENT COST	TIME COMMITMENT
Tidal Hydrology	Low	Low
Salinity	Moderate	Moderate
Plants	Low	Low
Invertebrates	High	High
Fish	Moderate	Moderate
Birds	Low	Moderate

SITE SELECTION AND SAMPLING LOCATIONS

Where are you planning to conduct your research? How many sites should you monitor? Should you monitor the entire marsh or just a portion of the total area? How do you decide what areas to monitor? Deciding which marshes to monitor and where to sample within these marshes are important tasks that should be resolved during the development of a study design. Some guidelines are provided below, and Chapters 4-9 provide more specific instructions on selecting sample locations.

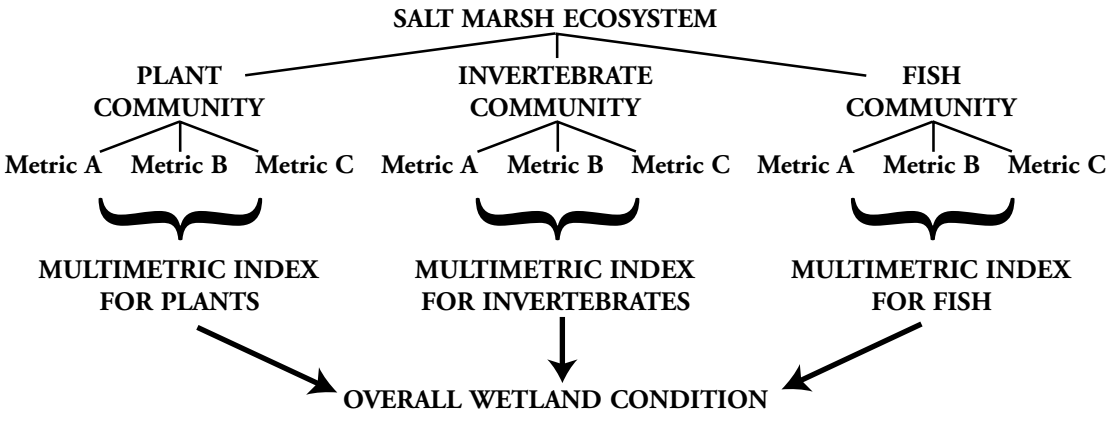
The Comparative Approach

The guidelines and methods described in this manual are based on a comparative approach. The basic premise of the comparative approach is that to understand how a **stressor** (such as a tide restriction or pollution) is affecting a salt

METRICS

Karr and Chu (1999) define a **metric** as an attribute expected to change in value along a gradient of human disturbance. Metrics have been tested for individuals, populations, communities, and ecosystems. This manual focuses primarily on population and community attributes such as taxonomic richness, relative abundance, species composition, and trophic structure. Metrics can be combined into a single **multiple metric index** for different biological communities, and these indices can be combined to provide a comprehensive measure of ecosystem health. The schematic diagram below illustrates this point.

Although this manual focuses on metrics, investigators may also want to explore descriptive or inferential statistics to analyze their data. Good sources of information on statistical treatment of biological data are Green (1979), Krebs (1985), Ott (1993), and Hayek and Buzas (1997).



COMPARATIVE APPROACHES

Example: Your group would like to study the effects of a tide restriction on a marsh, and you suspect that the tide restriction will be removed in two or three years. Your group may consider two different study approaches:

BEFORE-AFTER COMPARISON

Definition: Study a salt marsh before and after a stressor is added or removed.
Application: Study the restricted marsh for one or two years before the removal of the tide restriction and for a year or two afterward. Compare how salt marsh parameters change following the removal. Keep in mind that many natural processes respond slowly to change, and in many cases restored salt marshes will continue to evolve and respond for a long time.

REFERENCE SITE-STUDY SITE COMPARISON

Definition: Compare a salt marsh affected by a particular stressor to a similar salt marsh without that stressor.
Application: Use the restricted marsh as the study site and choose a suitable reference site. Usually the unrestricted portion (seaward side) of the salt marsh is a suitable reference site. Compare important parameters from the restricted side to the unrestricted side of the salt marsh. Your group can complete a meaningful comparison between the study site and reference site in one sampling season. This study will provide a lot of useful information that will help to plan for the actual restoration and to estimate restoration response. After the removal of the tide restriction, the reference site can serve as a trajectory to help evaluate how the study site is responding.

marsh, the characteristics of the marsh in the absence of the stressor must be understood. There are two primary ways to establish this comparison, including the Before-After Comparison and Reference Site-Study Site Comparison.

When it is feasible, volunteer groups should try to incorporate both a Before-After Comparison and Reference Site-Study Site Comparison into their monitoring program. Monitoring programs that are able to combine the two comparative approaches will provide much greater insight into the overall effects of a stressor. The Before-After Comparison allows groups to document the actual response of a marsh to the addition or removal of a stressor, and the Reference Site-Study Site Comparison allows groups to understand restoration targets and provide information and guidance for designing the restoration project.

The Before-After Comparison is not always possible, especially in instances where a group is interested in studying the effects of a disturbance that is already present and for which there is no restoration or remediation plan. For example, a group may want to know how an urban area (such as a large parking lot) is affecting a nearby salt marsh. The parking lot was built 20 years ago, and there are no plans to remove it. In this instance, the volunteer group has no choice but to compare the salt marsh to a nearby reference marsh.

Reference sites are salt marshes that lack some or all of the disturbances of the study sites. Reference sites are important because many of the impacts to salt marshes have occurred over relatively long periods of time, and it is usually not known what these sites were like prior to disturbance. Therefore, reference sites are used as reasonable approximations of conditions in the absence of a particular stressor. The selection of suitable reference sites is an extremely important part of the study design. The characteristics of reference sites will vary depending on the purpose, scope, and location of the investigation (Brinson and Rheinhardt, 1996). The limits of using reference sites are described in the next paragraph and in the section "Data Quality and Limitations."

One note of caution is that salt marshes may differ for reasons unrelated to pollution or disturbance. Tidal range, geology, landscape setting, and salinity are just some of the **variables** that influence salt marsh ecology. Ideally, study sites and reference sites are selected because they are similar in nearly every way except the stressor of interest. Project leaders should be aware of natural differences between study sites and reference sites, and address these differences when analyzing and presenting data.

When selecting reference sites, try to find sites in the same estuary or bay, perhaps even in the same salt marsh but in an area isolated from the stressor of interest. You should consider selecting at least two reference sites, such as one nearby the study site (for example, the unrestricted portion of a tide restricted salt marsh) and a second, more pristine marsh in your region. Throughout coastal New England, federal and state parks, town conservation areas, and nonprofit land trusts hold large areas of protected salt marsh that are practically void of human presence and therefore represent the least disturbed conditions at this time.

Three Common Study Areas

Volunteers will usually investigate one of three categories of salt marshes: marshes with tide restrictions, regional reference sites, and marshes affected by pollution or land use.

1. Salt Marshes with Tide Restrictions

A tide restriction is a reduction in normal tide range resulting from a completely or partially blocked channel. Roads, railroads, and other man-made creek crossings often bisect the marsh into a restricted side and an unrestricted side. The restrictive features of these crossings include undersized or blocked culverts, tide gates, or bridges that restrict full passage of tidal flow. For tide restriction studies, volunteers can use the unrestricted side as the reference site and the restricted side as the study site, because in the absence of the restriction it is assumed that the two sides would resemble each other. Volunteer groups that want to include another reference site can also select a regional reference site.

2. Regional Reference Sites

These salt marshes are generally as pristine as can be found today and include environmental conditions and biological diversity that are representative of a given region. Regional reference sites tend to be large expanses of salt marsh that are owned by conservation entities and are far from residential, commercial, and industrial development. Ideally, they lack linear or grid ditches that resulted from the Works Project Administration of the 1930s and other ill-begotten mosquito control or drainage projects. Certain recreational activities are permitted, such as bird watching, walking, or kayaking, but in general, these marshes experience little human disturbance. Regional reference sites represent the best achievable condition for salt marshes in a given region.

3. Salt Marshes Affected by Pollution and Land Use

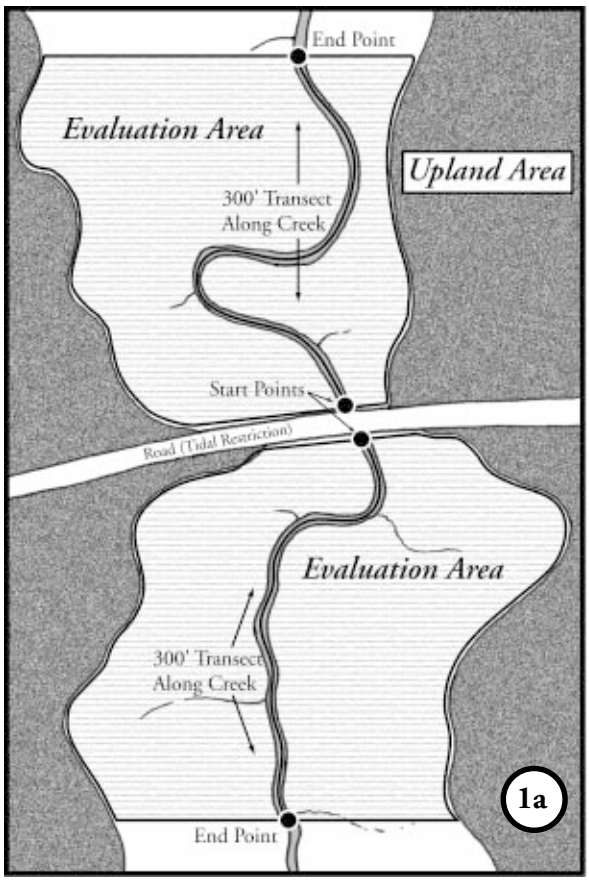
The types and intensity of surrounding land uses will affect the types and amounts of pollutants that enter coastal wetlands. Many people are interested in studying the effects of pollution and land use on salt marshes. It is difficult to choose reference sites for these types of study sites. One approach is to utilize one or more regional reference sites, with the understanding that there may be some environmental differences between the reference and study sites, such as location in the estuary, soils, topography, or tide exposure. Other reference areas could be parts of the same salt marsh that are farthest from the impacts, or nearby salt marshes whose upland habitat is relatively undisturbed. Project leaders should consult with agency scientists or other professionals when selecting reference areas for this category of study sites.

The Evaluation Area

Once you choose study sites and reference sites, you need to decide where to sample. Where should you put your vegetation **transect**? From what part of the tidal creek, bay, or salt pond should you collect invertebrates? This task may sound easy for a small salt marsh, but it can daunting in a 400-acre salt marsh! The study design needs to account for the wide variation in the sizes of salt marshes, reference sites and study sites that are different sizes, and environmental differences at different locations in a salt marsh (see textbox on page 3-8).

To address size variability, the authors have designed an approach to examine comparable portions of reference sites and study sites, called **evaluation area(s)**. The evaluation area is delineated as follows (Figure 1):

1. From a designated start point on the bank of the salt marsh creek, bay, or salt pond, extend a line along the bank edge for 300 feet (92 meters).
2. At both the start point and the end point, create another line (called a transect) that runs from the salt marsh banks to the upland edges.



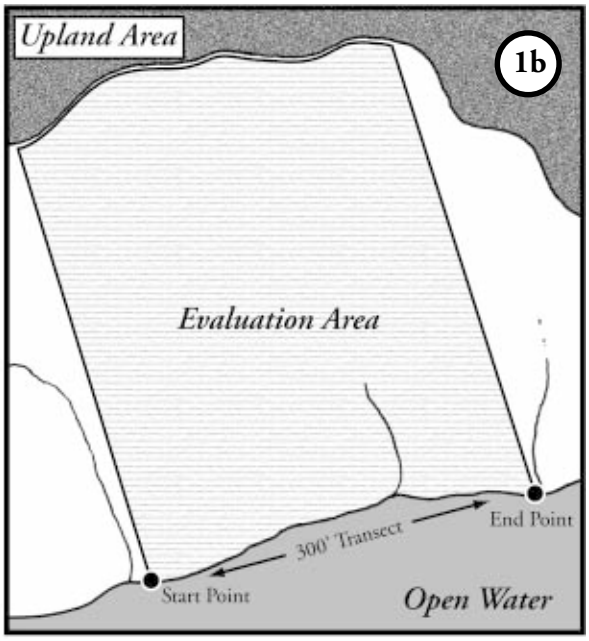


FIGURE 1. DELINEATING EVALUATION AREAS
Figure 1a shows the evaluation area on both sides of a tide restriction, and Figure 1b shows the evaluation area along an open-water feature. See text for details.

3. The habitat (salt marsh and creek channel) that falls between the two transects makes up the evaluation area.

Chapters 4-9 each provide specific instructions on selecting sampling locations for the different parameters.

DATA QUALITY AND LIMITATIONS

Throughout this manual, the authors emphasize how important volunteer monitoring can be and how volunteer data can affect conservation and management of natural resources. However, groups should also understand potential limitations of volunteer data and the importance of ensuring data quality. Quality assurance and quality control are of utmost importance for successful volunteer monitoring projects.

Cause and Effect

You have done everything right. You wanted to find out if a tide restriction was affecting a salt marsh in your community. You set up a sound study design and were very careful to select suitable reference sites. You collected excellent data on three parameters using procedures outlined in the manual. Your data clearly showed that the study site had poor habitat quality, a low diversity of plants and animals compared to the reference sites, and a higher proportion of **non-indigenous** and **invasive species**. You write up a report for your study and conclude that the tide restriction is to blame for degradation of the salt marsh. Does this mean you have correctly assessed the effect of the tide restriction on the salt marsh? Perhaps not…

It is important to understand that every study has its goals, objectives, and limitations. The approach detailed in this manual will indicate if two sites are different, but may not fully explain why they are different. In the above example, the tide restriction is most likely a major cause of the reduced diversity and increased **abundance** of invasive species, but other factors may be at work. For example, there may be a major **groundwater** seep in the study area causing substantial flows of fresh ground water, which naturally reduces the salinity. The expanse of *Phragmites australis* (common reed) that you measured may have been there

WHAT IS THE EVALUATION AREA AND WHY USE IT?

Your group is interested in examining the effects of a tide restriction (roadway and culvert) that has bisected a salt marsh into two parts — a six-acre restricted area and a 280-acre unrestricted area. You need to know where to survey the plant community. Here are two common concerns:

1. The unrestricted (reference) area is too big — nearly fifty times larger than the restricted marsh. Sampling the entire 280-acre salt marsh is not feasible or realistic. One plant transect might be a half-mile long!

2. Because of the size difference, you are apprehensive about comparing the restricted marsh to the unrestricted marsh — size alone would likely allow a greater diversity of plants to exist at the reference site.

To address these and other concerns, the authors of this manual have developed protocols to select representative areas of salt marshes called evaluation areas. Evaluation areas are delineated in a consistent way using specific protocols, and therefore reduce bias associated with size differences between different salt marshes. The location of the evaluation area is also important to isolate and assess the effects of land uses and related impacts like stormwater and fill.

for decades and expectations for removing this invasive species by eliminating the tide restriction may be overly optimistic. Other natural factors that you have not measured, such as the extent and duration of flooding and soil and water chemistry, strongly influence salt marsh biology. Finally, the confounding effects of other stressors such as commercial land use and stormwater discharges will make an accurate diagnosis more difficult.

Though we can never be entirely certain of cause and effect in comparative studies, we can overcome some uncertainty by using statistics and weight of evidence. Weight of evidence is the same in ecology as it is in law enforcement — the more we know about a situation, the more possibilities we can rule out. Volunteer monitoring projects that measure more parameters will be able to build a stronger case for their conclusions. However, volunteer monitoring groups often do not have the time or resources needed to conduct a study that is intensive enough to build an irrefutable case. We would all like to be the dazzling detective that presents our evidence to the speechless jury and wins the case handily, but the reality is environmental scientists are rarely 100% confident about their findings.

So why bother? Volunteer monitors can make important contributions to salt marsh protection and restoration without providing academic-level research. In many cases the data provided by volunteer groups help to identify salt marshes that deserve a closer examinations, such as a groundwater study, detailed soil and elevation mapping, or further chemical analysis. Another significant function of volunteer monitoring is to track specific parameters like vegetation, fish, and salinity in restoration projects. Observing and documenting the shift from one **community** type to another or the reduction of invasive species is sometimes as important as understanding exactly why these changes are occurring. Restoration, remediation, protection, and conservation efforts nearly always result from information provided by concerned citizens, groups, communities, and professional scientists.

Quality Assurance and Quality Control

One of the most difficult issues facing volunteer monitoring programs is data credibility. Decision makers and managers may be skeptical about volunteer data — they may have doubts that a group of concerned individuals can get together and collect scientifically sound data on a resource. The best way to address these concerns is to discuss issues of quality assurance and quality control during the study planning process. The terms quality assurance and quality control sound intimidating, but they are simply terms that refer to attentive and rigorous work. In any study, it is important that consistent protocols are used to complete data collection, storage, analysis, and reporting. With consistent procedures, volunteer monitoring

groups will be able to confidently compare one site to another and compare sites over time. Groups will be able to stand behind their work with conviction and satisfaction, knowing that they have been thorough in its completion.

In some cases, a state or federal agency may require or strongly suggest that your group develop a separate document called a quality assurance project plan, or QAPP. A QAPP outlines the procedures a monitoring project will follow, and includes methods of data collection, data validation, storage, and analysis. The authors have federal and state-approved QAPPs for the study design, methods, and procedures outlined in this manual. Several organizations provide assistance to volunteer groups who are developing a QAPP. The U.S. Environmental Protection Agency has a document called *The Volunteer Monitor's Guide to Quality Assurance Project Plans* (Hunt et al., 1996). Also, the Massachusetts Waterwatch Partnership offers hands-on support for volunteer groups engaged in developing a QAPP or study design, and their website is http://www.umass.edu/tei/mwwp/. Finally, there are many different individuals and organizations that can be contacted with questions or request for support (Appendix A).

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